EE225E/BIOE265 Spring 2012 Miki Lustig
Principles of MRI

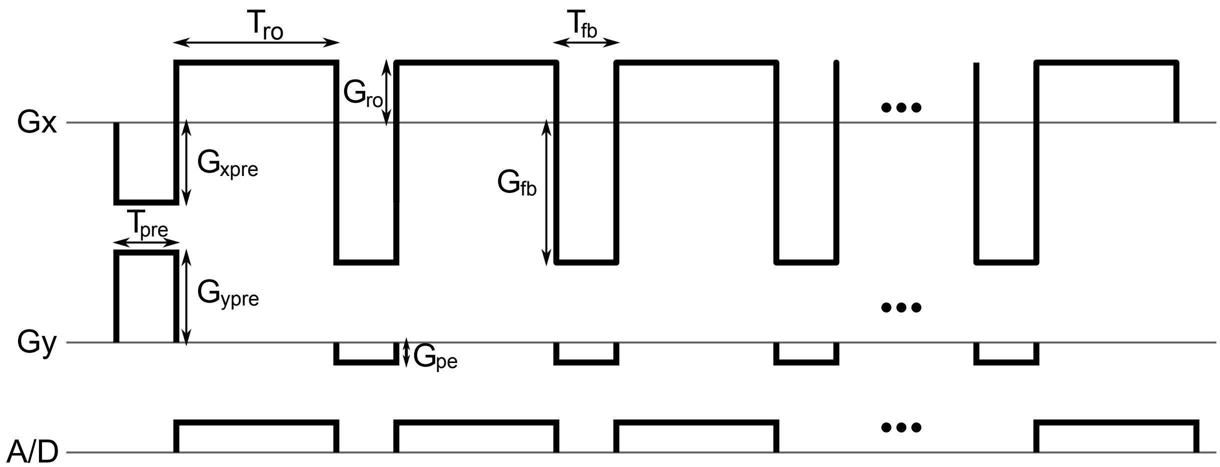
Assignment 6

Due March 4, 2010

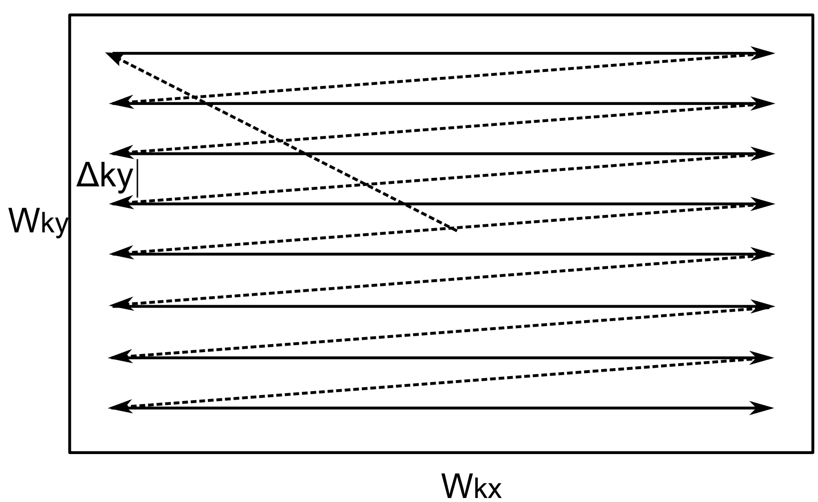
1. Read Nishimura Ch. 6

2. *From midterm I, 2011. FlyBack EPI Trajectory Design*

   Your friend gives you the following sketch of a gradients sequence that he says has very interesting properties. In the sketch, the timing and the gradients amplitudes **are not drawn to scale**.



   These gradients are supposed to traverse a so called "Fly-Back EPI" trajectory similar to this:



   T_{pre} is the length of the prewinder, T_{ro} is the readout duration for one line, T_{fb} is the flyback duration, G_{xpre} and G_{ypre} are the x-gradient and y-gradient prewinders amplitudes, G_{ro} is the x-gradient readout amplitude, G_{fb} is the x-gradient fly-back amplitude.

You would like to design a Fly-Back trajectory for your sequence that will have: $N_{ro} = 100$ readout points, $N_{pe} = 50$ "phase-encode" (k_y lines), bandwidth-per-pixel $BWPP = 1000$Hz/pixel, readout field of view $FOV_{ro} = 20$cm and phase-encode FOV $FOV_{pe} = 20$cm. The maximum gradient amplitude of the system is $G_{max} = 5$ G/cm. In this question $\frac{\gamma}{2\pi} = 5000$ Hz/G.

Answer the following questions:

a) Find W_{kx} and W_{ky}, the extent in k-space in the readout and phase-encode directions. Find the spacing between phase encode lines in k-space,e.g., Δk_y.

W_x =	W_y =	Δk_y =

b) What are T_{ro}, and G_{ro}?

T_{ro} =	G_{ro} =

c) What are T_{pre}, T_{fb}, G_{ypre}, G_{xpre}, G_{fb} and G_{pe} that will result in the shortest total duration of the gradient waveforms? What is the total duration T_{tot} (excluding the prewinder)? What is the scan efficiency (The scan efficiency is defined as the ratio between the total time spent collecting data and T_{tot})?

T_{pre} =	G_{xpre} =	G_{ypre} =	T_{fb} =
G_{fb} =	G_{pe} =	T_{tot} =	$\%eff$ =

d) You would like to scan faster. What is the BWPP that will result in the shortest total duration T_{tot} ? Compute T_{tot}. What is the scan efficiency in this case? What is the factor of reduction in time compared to (c)?

$BWPP$ =	T_{tot} =	$\%eff$ =	reduction factor =

e) In this part, the slew-rate can not be neglected. Qualitatively answer and briefly explain how would it affect the factor of reduction?

Reduction factor: ( ) Lower ( ) Same ( ) Higher.
Briefly Explain:

3. *From midterm I 2011. Properties of FlyBack EPI Trajectory*

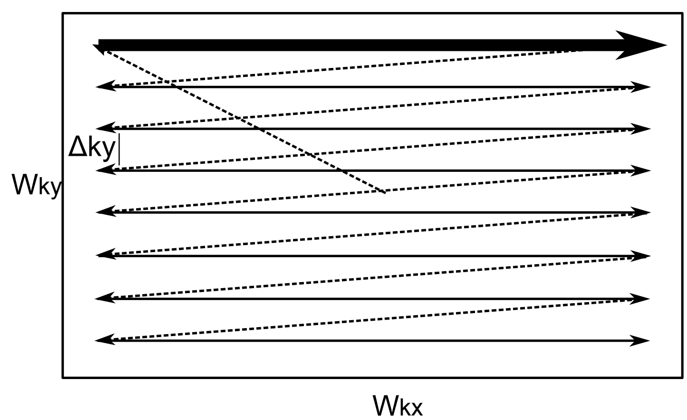
In the following part we will analyze the properties of the Fly-Back EPI trajectory as presented in problem 2. We will consider a trajectory with the following parameters: $N_{ro} = 128$, $N_{pe}=64$, $FOV_{ro} = 25.6$cm, $FOV_{pe} = 25.6$cm, $G_{ro} = 2$G/cm, $T_{ro} = 0.5$ms, $T_{fb} = 0.5$ms, $\Delta k_y = \Delta k_x = \frac{10}{256}$, $\frac{\gamma}{2\pi} = 5000$Hz/G. (The rest are unnecessary for this question).

a) What would be the effect on the reconstructed magnitude image $|m(x,y)|$ if the A/D window is delayed by $t = 1/256$ms.

Reconstructed $|m(x,y)|$ =

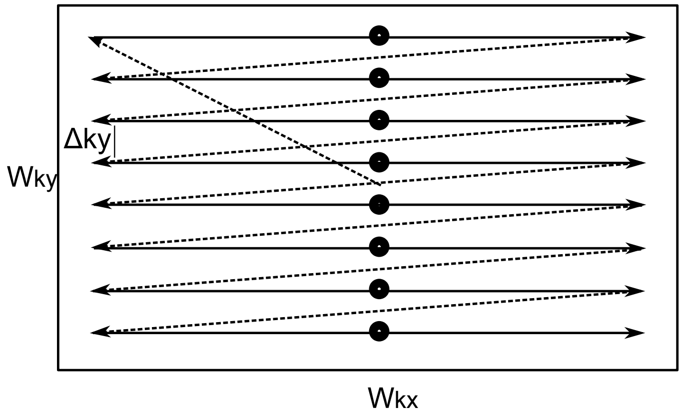
Now, we will examine the effects of off-resonance. We will consider an impulse image located in the center of the magnet, $m(x,y) = \delta(x,y)$ with its corresponding k-space $M(k_x,k_y) = \mathcal{F}\{m(x,y)\}$. The spin has a resonance frequency shift that is higher by $\Delta f = 200$Hz with respect to the demodulation frequency of the scanner. We are assuming a dumb reconstruction machine that is not aware of the frequency shift.

b) Consider only the 1^{st} readout window (or the first k-space line as seen in the figure below). What is the received signal as a function of k_x? e.g., $s(k_x) = M(k_x, k_y = 2.5)$.



$s(k_x)$ =

c) Now, consider consider the signal made of samples in the center of all the readouts (as shown in the figure), e.g., $s(k_y) = M(k_x = 0, k_y)$



$s(k_y) =$

d) Using what you got from (b) and (c), what is the reconstructed magnitude image $|m(x,y)|$. Explain intuitively what is going on. What is the more dominant effect?

$|m(x,y)| =$

4. Nishimura assignment 6.5

5. If we use a 90° degree excitation for imaging, all of the initial M_z magnetization is used up by each excitation, and we have to wait for it to rebuild before we can acquire each phase encode.

   An alternative is to use a sequence of small-tip-angle excitations θ_i for $i = 1 : N$. The first pulse θ_1 produces a transverse magnetization

   $$M_{xy,1} = M_0 \sin\theta_1$$

   and leaves a longitudinal magnetization

   $$M_{z,1} = M_0 \cos\theta_1$$

   After a short interval T_R, the repetition time, the transverse magnetization has decayed away, but $M_{z,1}$ remains (T_1 is long compared to T_R, and T_2 is short compared to T_R). We can then apply a second pulse θ_2 to create a second transverse magnetization

   $$M_{xy,2} = M_{z,1} \sin\theta_2$$

   leaving a second longitudinal magnetization

   $$M_{z,2} = M_{z,1} \cos\theta_2.$$

   We continue this way for N pulses until $M_{z,N} = 0$, and all of the magnetization has been used up.

   a) Show the remarkable result that we can choose θ_i so that each transverse magnetization is

   $$M_{xy,i} = \frac{M_0}{\sqrt{N}}.$$

   For example, with nine pulses, we could produce nine transverse magnetizations each of amplitude of $M_0/3$. This seems like three times more magnetization that we are entitled to!

   b) Find the θ_i sequence that produces this sequence of transverse magnetizations.